PRACTICAL INPUTS
FOR
HYPERLOOP TRANSPORT ADOPTION
REV1.1
(AN APRIL 2024 REVISION OF THE NOVEMBER 2020 ORIGINAL)

Introduction

The early adoption and then more widespread use of transportation systems that both save money and increase profitability is not a new idea for entrepreneurs, scientists and governments and is a goal they aspire to achieve. Everyone wants to innovate or create the latest big thing that pushes society forward toward a yet brighter and safer future hopefully for a large profit or a significant social benefit.

I have taken that paradigm and pushed it yet another step forward by offering some inputs that may take the Hyperloop Transport concept a few steps closer to reality.

Also, I normally espouse the adoption of stepchange technologies that can offer least cost operation for least risk without the need for hydrocarbon energy sources. In this instance that is certainly proves to be true.

This conceptual strategy encompasses using a highly efficient non-hydrocarbon energy source and other closely integrated emerging technologies that already exist and that can, when combined, bring the Hyperloop to life rapidly. It may not offer the large profits for existing stakeholders that are usually an expectation, but even then, most would endorse a least cost, least risk approach that offers a predictable profit. Some others may attempt a catch and kill approach regardless because change is a risk, and they are deeply vested in alternatives.

Answering “why” would I do this conceptual effort might be vital this point. Why – because we were in the grip of a global pandemic that changed and largely disrupted our global

economy in a staggeringly short period of time. I suspect and believe that something similar will happen again.

Finding the way to recover our economy and its various supply chains while also conquering a pandemic (and others yet to come) becomes a first order priority. This dire situation could use this author's modest work as outlined herein to positive effect as a portion of a recovery strategy if even in a small way.

A sizeable resource and research publication library has been assembled and should be used accordingly if interest proves favorable.

Replacing hydrocarbon fueled powergen systems that also allow for sustained operation with a simple, easily maintained system has many obvious implications for both market development and rollout and its profitability. Affording to do the development and rollout can be easily done using the energy tax model this author has outlined many times in the recent past.

Concept

An Hyperloop explanation is below. It may be helpful:

"The **Hyperloop** is a proposed mode of passenger and freight transportation, first used to describe an open-source vactrain design released by a joint team from Tesla and SpaceX.[1] Hyperloop is a sealed tube or system of tubes with low air pressure through which a pod may travel substantially free of air resistance or friction.[2] The Hyperloop could convey people or objects at airline or hypersonic speeds while being very energy efficient.[2] This would drastically reduce travel times versus trains as well as planes[2] over distances of under approximately 1,500 kilometers (930 miles).[3]

Elon Musk first publicly mentioned the Hyperloop in 2012.[4] His initial concept incorporated reduced-pressure tubes in which pressurized capsules ride on air bearings driven by linear induction motors and axial compressors.[5]

The Hyperloop Alpha concept was first published in August 2013, proposing and examining a route running from the Los Angeles region to the San Francisco Bay Area, roughly following the Interstate 5 corridor. The Hyperloop Genesis paper conceived of a hyperloop system that would propel passengers along the 350-mile (560 km) route at a speed of 760 mph (1,200 km/h), allowing for a travel time of 35 minutes, which is considerably faster than current rail or air travel times. Preliminary cost estimates for this LA–SF suggested route were included in the white paper—US$6 billion for a passenger-only version, and US$7.5 billion for a somewhat larger-diameter version transporting passengers and vehicles.[1] (Transportation analysts had doubts that the system could be constructed on that budget. Some analysts claimed that the Hyperloop would be several billion dollars overbudget, taking into consideration construction, development, and operation costs.)[6][7][8]

The Hyperloop concept has been explicitly "open-sourced" by Musk and SpaceX, and others have been encouraged to take the ideas and further develop them. To that end, a few companies have been formed, and several interdisciplinary student-led teams are working to advance the technology.[9] SpaceX built an approximately 1-mile-long (1.6 km) subscale track for its pod design competition at its headquarters in Hawthorne, California.[10] Virgin Hyperloop conducted the first human trial with Virgin Hyperloop executives Josh Giegel, its Chief Technology Officer, and Sara Luchian, Director of Passenger Experience as the first passengers at a speed of 172 km/h (107 mph) at the Virgin Hyperloop's DevLoop test site in Las Vegas, Nevada.[11][12]".

My concept integrates both on board powergen using an expanding gas turbine combusting gaseous hydrogen and oxygen and on-board battery supply. Externally,

acceleration, cruise and deceleration would be via coilgun type electromagnetic coils and maglev type suspension systems. E-stop and battery supply would be via on board EGT and short duration exhaust nozzle suspension. Braking would be eddy current in all operational modes.

My (not new nor solely my own) power generation system will create its own fuels from atmospheric gases (hydrogen and oxygen) present in the transport tube. Then via a proven hydrogen / oxygen expanding gas combustion turbine drive to a coupled power generator that will charge a dedicated bank of sized for the application batteries (think TeslaWall). Said batteries will supply the AC local onboard grid on a demand basis. The system can be designed for 24/7/365-day operation with at least 12 months before first periodic port maintenance.

The forms of “emission” from this power generation system would be excess to need heat and water. Heat and water will need to be controlled within the tube and its capsule anyhow. I expect this small, intermittent source will be of no concern.

An illustration of the basic EGT process also with some notes by others is below:

“PROCESS DESCRIPTION OF A GRAZ CYCLE PLANT FOR HYDROGEN COMBUSTION

Figure 1 shows the principal flow scheme of the Graz Cycle plant for hydrogen combustion, and Fig. 2 the associated temperature-entropy (T-s) diagram generated by the software IPSEpro. The plant is based on a proposal by Jericha [9] and consists basically of a high-temperature Brayton cycle and a low-temperature Rankine cycle – a combined cycle. The Brayton part consists of the combustion chamber (CC), the high-temperature turbine (HTT) and the compressors (C1/C2). The Rankine steam loop consists of the heat recovery steam generator (HRSG), high-pressure steam turbine (HPT), low pressure steam turbine (LPT), condenser, condensate pump, deaerator and finally the feed pump supplying high pressure water to the HRSG.

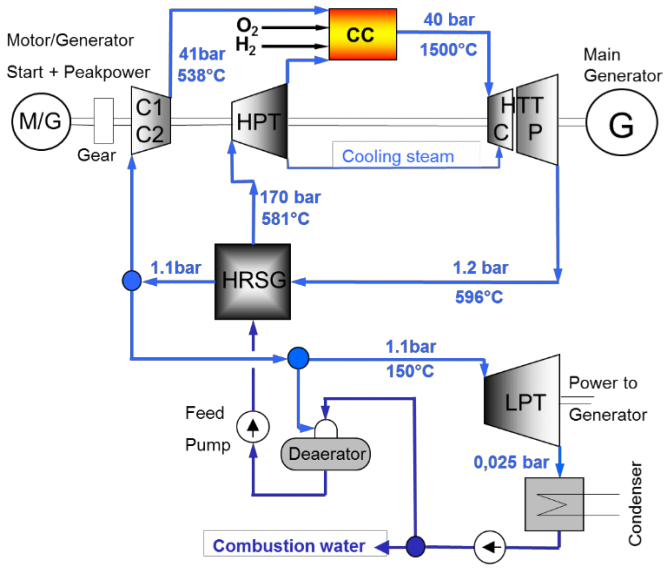


Fig. 1: Principal flow scheme of the Graz Cycle for hydrogen/oxygen combustion"

Maintaining consistent and predictable power generation is key for this process to work. The key is aggressive heat management as shown above.

Put another way: "Generally, unlike the heat rate, the net power output from a gas turbine decreases with an increase of the ambient air temperature. This is due to reduced net power output, which is directly proportional to the air mass flow rate; net power produced decreases when the ambient air temperature increases. Practically, a 25% loss of the rated power capacity of the gas turbine at ISO conditions as the ambient temperature reaches 40 °C is reported."

Given that this process issue can be easily overcome by design then this concept then becomes compelling given the application at hand.

In all instances all sub-systems are well proven. No new technology is required.

This author knows that a consistent and appreciable volume of relatively pure H2 / O2 are needed.

My concept description for this is just below as text (see next page):

A compressor driven raw atmosphere intake contacts a set of three sequentially mounted molecular sieves that would remove [1]water vapor, [2]methane/carbon dioxide and [3]nitrogen from the intake atmosphere volume. The “concentrated” downstream “gas” would be 90%+ oxygen would be compressed in a storage tank and directly used in the combustion process.

Then the molecular sieve separated [2]methane/carbon dioxide would be purged or cleaned from its’ molecular sieve using a small volume of the compressed oxygen on a timed basis. The purged volume of methane/carbon dioxide/oxygen would be captured, compressed, and then processed at low pressure (<2bar) and ambient temperature through a photoelectrochemically powered tubular or sheet assembled, optically clear, covered methane “reformer” or “cracker” to make a compressed hydrogen and oxygen product with a small volume of residual of carbon dioxide as a contaminant. The [1]water vapor molecular sieve would be similarly purged with the excess [3]nitrogen gas on a timed basis with the balance of the nitrogen vented to the tube’s atmosphere and then vented as outline in my attached notes.

Commercially this atmospheric gas separation can be described as a VSA, PSA or VPSA any of which could work. Commercial vendors for the appropriate molecular sieve materials and the gas separation systems exist and should be thoroughly explored and then used as appropriate.

Commercially this system will be attractive from both a cost to construct and use (deploy) perspective especially when compared to either conventional or other unconventional (renewable) energy systems.

Alternatively, if the onboard hydrogen supply is too small, compressed methane or natural gas could be used although this would assume that some form of on demand logistic supply was available.

This author has previously specified use of magnetic bearings and transmissions for all applicable systems for similar applications. These are widely available and nicely sized for these applications which would eliminate most of the problems found with rotating machinery and their maintenance.

Again, this author does advocate close integration with other renewable energy generation and storage systems to increase supply optionality in the event of a national and / or regional grid outage of significant duration.

Hyperloop Summary Notes

Goals:

- Goal 1: Nextgen mixed use hyperloop tube and capsule is the innovation target for this effort.
- Goal 2: Nextgen mixed use hyperloop tube and capsule must be capable of first beneficial use within 5 years.
- Goal 3: Nextgen mixed use hyperloop tube and capsule must be least cost, least risk.
- Goal 4: Nextgen mixed use hyperloop system must be hydrocarbon combustion free.
- Goal 5: Nextgen mixed use hyperloop tube and capsule must be robust for >1M mile service life.
- Goal 6: Nextgen mixed use hyperloop tube and capsule must be operable in all topography's and climates.

Monday, April 1, 2024

Notes (no order):

- All components must be capable of in place maintenance and replacement.
- All components or their associated critical duty items.
- All external power generated shall first charge on board batteries.
- All external power supplied shall be AC for capsule operational needs.
- All mission critical replacement components must be local stocked.
- All onboard control systems to be hardened 24VDC.
- All onboard power systems to be AC.
- Deployment of said system into full operation shall not be more than one minute from a dead start with charged batteries (insight).
- Atmospheric emissions shall be low temperature water vapor and trace amounts of NOx and CO2 well below background levels (insight).
- H2/O2 expanding gas turbine power generation must be capable of supplying all on board power needs plus E-stop requirements plus at least 25% of peak demand into the on-board storage battery / ultracapacitor banks.
- Onboard AC /HVAC needs qualify for integration with a 6 - 10% inversion penalty.
- Power systems must be capable of 99%+ uptime operation.
- Power systems must be capable of sustained stand down or storage - on the order of years with no penalty (insight).
- Power systems must be fully capable of offline no external access operation (insight).
- Power systems shall be capable of 24/7/90 day operation before significant onboard maintenance.
- Molecular sieve materials must be fines removal pre-sieved then triple bagged with an appropriated desiccant for long-term on-board storage.
- PSA / VPSA or VSA must provide a 90%+ gaseous O2 product @ 2 bar pressure.

- PSA / VPSA or VSA must provide a 90%+ methane / CO2 blended product @ 2 bar pressure.
- PSA / VPSA or VSA must provide a 90%+ nitrogen product suitable for direct emission or other onboard uses such as fire suppression (insight).
- Power systems must be easily integrated and coupled / decoupled with existing onboard drive systems.
- Power system turbines should be two or more output shaft capable to provide flexibility in drive and onboard power system integration and / or repair while at work.
- Said power systems batteries must be capable of providing at least +100% of peak demand for a 1-hour span (insight).
- Power systems must be of unitized construction and capable of 4-hour changeout in depot (insight).
- Said systems must provide enough power for mission critical sub systems.
- Startup external power supply shall be capable of 10-minute deployment support.
- Ultracapacitor components shall be capable of multiple recharges from the battery outputs.
- Ultracapacitor components shall be provided suitable for startup and local or brief operational needs (insight).
- Ultracapacitor output shall be on board DC or AC voltage / amperage selectable (insight).
- Eddy current suspension and brake motors shall take power from on board high voltage batteries only (insight).
- On board batteries shall be capable of meeting stand-alone operation for not least than 2 hours of sustained operation (insight).
- Sustaining H2/O2 EGT combustion will require on-board compressed gaseous supply (insight).
- Keeping the on-board batteries charged as necessary so that the suspension and brake motors can demand respond is the EGT' normal goal (insight).

- Batteries to be LiON or better and capable of sustained operation.
- Eddy current regenerative braking systems including dielectric fluid cooling shall be integrated (insight).
- Eddy current suspension motors and suspension must be AC not DC to mitigate resistor heat issues.
- Traction motors shall use a vaporizable dielectric fluid for heating / cooling.
- Radiators for dielectric fluid cooling may be externally mounted on the locomotive or on the following cars by serial connection (insight).
- Heating / cooling of the cars shall be by radiator chilling or EGT heating of the non-hazardous dielectric fluid which may be palm oil or a derivative (insight).
- Alternatively, externally supplied compressed hydrogen shall be provided and supplied from an on-board tank of appropriate design.
- Said PSA (s) may be single but should be parallel installed for redundancy (insight).
- Inlets for the PSA's shall be face mounted into on-board compressor assemblies to feed the PSA MOF vessels (insight).
- All on-board process heat exhausts shall be vertical and common in a single stack.
- External control systems shall be optimized for both on time people and goods delivery at least cost and least risk.
- On board control systems shall include control and use of cooling / heating AC drive motor's dielectric fluid and continuous track monitoring for parallel spacing and displacement (insight).
- It shall have a 750-mile range maximum.
- No intermediate stops between entry and exit are foreseen.
- Current distance basis is centered on Los Angeles CA to San Francisco CA.
- It shall be limited to passengers, luggage, and small freight items like conventional air freight.
- Speed shall be not more than 0.95 - 0.98 mach at MSL with a partial vacuum.

- Speed limit is meant to avoid a shock wave.
- Speed modes shall be acceleration, cruise, and deceleration.
- Speed shall therefore be ~ 650 mph during cruise phase.
- Speed shall be during acceleration / deceleration not more than 1 G maximum on the horizontal plain.
- Technology limitations assume that system have two major components - capsule and tube.
- Tube is assumed to be partially evacuated to minimize both a bow wave and friction losses between tube and capsule.
- Tube assumed to be metallic in nature and very probably thin wall stainless steel.
- This author assumes that capsule atmospheric control is assumed to be self-contained for the flight's duration.
- This author assumes that passengers shall not have on board access to waste facilities.
- This author assumes that E-stop function has not been defined.
- This author sees E-stop as emergency stop that shall not exceed 1G maximum deceleration.
- This author sees E-stop portals to be hard ports in tube wall at known intervals with proper imbedded controls and that shall be easily accessed from tube inside and outside.
- This author sees capsule that shall have imbedded E-stop feature with cascading features such as tube pressure, capsule pressure, temperature and exit access proper interlocks.
- This author sees E-stop recovery shall be via remote control only.
- This author assumes that envisaged range is not a hard number and may be much shorter or much longer than 750 miles.
- This author proposes that E-stop deceleration may be imbedded but emergency only EGT assisted with directional nozzles suitable for a single time use from maximum speed and load in full atmosphere (insight).

- This author proposes that tube is not evacuated with propulsion provided via his HSR concept (insight).
- Alternatively, tube may be ground mounted concrete or composite tube with PRV's of sufficient diameter and radial spacing to prevent a bow wave at maximum velocity (insight).
- Eddy current braking shall be design standard and used to charge on board battery packs.
- Capsule shall be of largely non-ferromagnetic materials (insight).
- Tube shall integrate humidity controls spaced at defined intervals with water discharged outside tube (insight).
- Cassette type foamed metal heat sinks at each capsule end shall be used to manage both capsule interior and tube exterior temperature within a specified range (insight).
- Cassette type foamed metal heat sinks shall be removed after each trip passage or station and used as heat source for heat engine power generation or regeneration (insight).
- Emergency tube interior foamed metal heat sinks shall be spaced on the tube's exterior at routine intervals with appropriate tube exterior radiator of passive operation design (insight).
- Capsule interior atmosphere shall be maintained from EGT inlet compressor bypass (insight).
- Capsule shall have external surface mounted highly conductive linear accelerator bands meant to mesh effectively with external coilgun acceleration system (insight).
- Capsule exterior and tube interior shall use full diameter conductive external bands as "maglev" type suspension powered both by on board batteries and external cruise coilgun stations spaced at routine intervals on the tube exterior (insight).
- On board EGT exhaust may also power suspension nozzles during cruise or deceleration phases such as an E-stop or power outage condition (insight).
- Tube interior lighting may be provided during an E-stop condition via PRV normally open solenoid power loss condition (insight).

- Tube and all tube exterior appurtenances shall be full earth grounded during an E-stop event (insight).
- Capsule and tube dimensions and capacities shall be constrained by "maglev" type suspension requirements (insight).
- Tube seating shall have a vertical axis post suitable for two position orientation such as "forward" during entry, acceleration, and cruise and "rearward" during deceleration, exit and E-stop conditions (insight).

Conclusion

This unit, its various technologies and its intent are meant to solve the pressing need for a critical application - high speed least cost and risk for mixed use rail “trains”. It is meant to be easily fit and repeatedly deployed. It is meant to be “hack proof”. It can not only provide fully scaleable power (or much more) but also a significant volume and consistent source of potable drinking water for onboard use and heat. It only needs our atmosphere and some humidity to work which should not be too difficult to find.

Takeaways

- Handling compressed (not liquified) gases is easy with its closely associated hardware widely available for commercial purchase and safe use.
- Non-hydrocarbon expanding gas combustion is not new science just new for this application.